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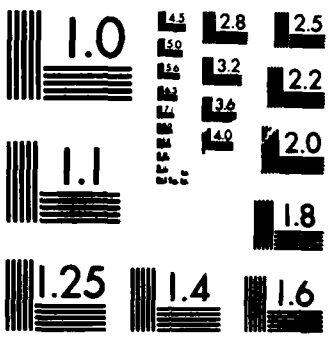

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FINAL REPORT

to

OFFICE OF NAVAL RESEARCH

ONR Contract No. N00014-84-K-0243

for

OPTIMAL LIST METRIC RECEIVERS FOR SPREAD SPECTRUM MULTIPLE ACCESS RADIO NETWORKS

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October 1986

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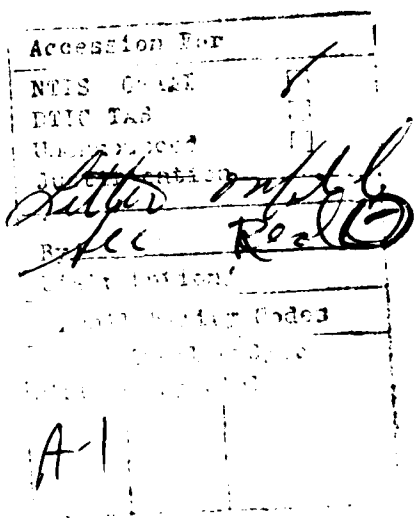
PREFACE

This grant funding dates were from January 20, 1984 through April 19, 1986. Quarterly progress reports were submitted throughout this period. During this grant period work based on this research was reported in a three volume series of books titled SPREAD SPECTRUM COMMUNICATIONS published by Computer Science Press in 1985, in the Ph.D research dissertations of Phil Lee, Mark Creighton, and Quang Vo, and in several papers in referred journals and conferences.



SUMMARY OF RESEARCH

Introduction

Research conducted under this grant studied the performance of various receivers for Frequency Hopped M-ary Frequency Shift Keyed Signals in jamming and multiple access environments. This work was divided into two parts:

1. Analysis of Conventional List Metric Receivers

2. Analysis of Optimal Multiple Access Receivers

Conventional list metric receivers were examined for both jamming and multiple access channels by Mark Alan Creighton as part of his Ph.D dissertation research. This work has been completed and Mark Creighton has obtained his Ph.D based on this work. The second part of this grant research has been conducted by Quang Vo as his Ph.D dissertation research. This part examined the performance of optimal and suboptimal multiple access receivers. The result of this work is a very practical multiple receiver design that performs almost as well as an ideal optimal receiver for M-ary FSK signals. Quang Vo has completed this research work and is now writing his dissertation.

Part I

Mark Alan Creighton completed research on this grant and reported it in his Ph.D dissertation titled FREQUENCY HOPPED M-ARY FREQUENCY SHIFT KEYED COMMUNICATIONS USING LIST METRIC DECODING OVER JAMMING AND MULTIPLE ACCESS CHANNELS. Analysis of list metric receivers under various channel conditions are very difficult to do and required extensive modelling and computer analysis. This 360 page dissertation provides the most extensive study of list metric receivers and shows their effectiveness against tone jamming and interference from other similar signals. The results of this study reinforced our initial belief that list metric receivers are practical and effective in the worst type of jamming and multiple access environments. Several journal papers are now being prepared based on this research.

Attached to this report is the title page and abstract of Mark Creighton's Ph.D dissertation.

Part II

Quang Vo has completed his part of this research and is currently writing up this work in his Ph.D dissertation titled OPTIMAL

MULTIPLE ACCESS RECEIVERS FOR M-ARY FREQUENCY SHIFT KEYED SIGNALS. This work required a combination of modelling, mathematical analysis, and computer evaluations of performance equations. Vo compared the performance of the conventional receivers in a multiple access environment with various optimal and suboptimal receivers. Optimal multiple access receivers perform considerably better than conventional receivers but they are generally very complex and impractical. One of the main results of this research is the design and analysis of a suboptimal receiver that performs close to the optimal receiver and is relatively easy to implement. Its complexity grows linearly with the number of multiple access signals whereas the optimal receiver grows exponentially with this number.

Quang Vo's dissertation will be completed in January 1987. At that time copies will be sent to ONR.

Conclusion

The research conducted in this grant examined the performance of potentially practical receiver designs that achieve good performance in jamming and multiple access environments. The list metric receivers perform well in a "worst case" jamming environment and do not degrade much from more commonly used receivers in other jamming conditions. In a multiple access channel a practical suboptimal receiver was found and analyzed.

The work on this grant required careful modelling, difficult mathematical analysis, and considerable computer evaluations of the derived performance equations. We were successful in completing all the tasks of this grant.

UNIVERSITY OF CALIFORNIA

Los Angeles

Contract N00014-84-K-0243

Frequency Hopped M-ary Frequency Shift Keyed Communications Using List Metric Decoding Over Jamming and Multiple Access Channels

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy in Electrical Engineering

by

Mark Alan Creighton

AD

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1986

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My wife, Marcy, deserves a most special thank you for her enduring support and patience. I thank my mother, Carol, from whom I first learned the value of education. And to my newborn Beth, thank you for placing this all in a new perspective.

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ABSTRACT OF THE DISSERTATION

Frequency Hopped M-ary Frequency Shift Keyed
Communications Using List Metric Decoding
over Jamming and Multiple Access Channels

by

Mark Alan Creighton
Doctor of Philosophy in Electrical Engineering
University of California, Los Angeles, 1986
Professor Jim K. Omura, Chair

List metric decoding is applied to anti-jam and multiple access communication systems that employ frequency-hopped, M-ary Frequency Shift Keyed (MFSK) modulation. The performance of these systems over Gaussian noise and Rayleigh fading channels is analyzed by deriving expressions for the cutoff rate parameter R_0, and evaluating numerical examples. R_0 represents the largest reliable data rate per coded symbol that could be achieved, with a particular system and channel, by using practical coding methods. Because it is code-independent, R_0 is used as the basis for comparing list decoding against hard and soft decisions, without the encumbrance of analyzing specific error correcting codes. R_0 is then used later, along with a

code-dependent function, to upper bound the bit error probability provided by a particular code.

In a list decoding receiver, decisions are based on the relative magnitudes of the demodulator's energy detector outputs. Energy-ordered lists of the M MFSK symbols are sent to the decoder instead of the detector outputs themselves, as is done in soft decision receivers. This arrangement offers several performance and implementation advantages over other receiver structures. For instance, pure soft decision receivers are known to be vulnerable to certain forms of multiple access interference and jamming. Receivers which quantize detector outputs are less vulnerable, but then Automatic Gain Control (AGC) must be implemented, and effective AGC is often difficult to maintain. In contrast, list decoding requires no AGC because only relative comparisons are made. By using abbreviated lists, list-of-L decoders can also provide superior performance for applications where the decoder memory is limited. Because hard decisions are equivalent to list-of-1 decisions, list-of-L decoding can be viewed as a generalization of hard decision decoding, and as such is shown to provide better performance.

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